DISCUSSION

One can not but admire the courage of Professor Exner in undertaking with the small number of meteorological stations available to discuss the elusive problem of the form, extent, and apparent movement of areas of positive and negative temperature anomaly that appear daily on weather charts for the Northern Hemisphere.

The question naturally arises, What approach to accuracy is obtained by the use of a small number of stations? The present writer undertook to compare the results for North America with the twice daily forecast charts for the corresponding period made and filed in the United States Weather Bureau Forecast Division. Naturally, because of the closer network of stations used in drawing those charts, material differences were found and some areas of positive or negative temperature anomaly came to light which the highly generalized charts of Professor Exner did not show.

In the absence of a detailed comparison of the two sets of charts it is impossible to say to what, if any, extent the general conclusions of the author might be changed.

The Weather Bureau charts present the departures from normal temperature of the current 8 a. m. and 8 p. m. temperatures (seventy-fifth meridian time). Obviously these departures would be slightly different were the daily mean temperatures considered. In any event the labor of making an accurate check of the results of the two sets of charts is prohibitive.

THE WEATHER SITUATION IN EUROPE IN THE WINTER OF 1928–29 [1]

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By F. M. EXNER

In February, 1929, the cold was very abnormal over all Europe; at Vienna on the morning of the 11th there was recorded a minimum of −14.8° F., a temperature that had not occurred at that point since the establishment of the station; that is, since the year 1775. In the course of the 154 years, during which observations have been made regularly, a temperature of −4° or lower was recorded 14 times; the lowest reading previous to this year was −11.2° in January, 1850. The 14 instances of very low temperature show no regularity as to time of occurrence; no period relative to the coldest years can be determined. On the morning of February 11 the severity of the cold just above the ground was a striking feature; while the reading was −14.8° at an elevation of 2 meters, it was −25.6° a few centimeters above the surface of the snow. This lowering of temperature was caused by radiation from the snow to the clear sky. Immediately below the surface of the ground the temperature was 14°; at depths of 2 centimeters, 50 centimeters; and at 1 meter the readings were 17.6°, 28.4°, and 35.6°, respectively. In the snow and in the ground conduction of heat is rather slow, so with clear sky in winter the surface of the earth is very strongly cooled through outward radiation.

The cold of winter is, of course, mainly the result of outward radiation. Since in our winter the sun has its position south of the Equator, the duration of solar radiation and its intensity in the Northern Hemisphere are considerably less then than in summer; in the tropical region the radiation of heat from the sun is great even in winter and then exceeds the outward radiation from the earth's surface to space; that is, the tropical region has an influx of heat even in that season. The regions of our latitudes, and the polar regions especially, have, however, in winter more outward radiation than insolation and there thus results in these higher latitudes a loss in heat.

Despite this continuous loss of heat through outward radiation in winter we do not regularly have a continuous cooling, but often a stableness in temperature or even an increase therein; this is possible only through supply of heat from lower latitudes accomplished by transportation of air. Normally the western part of Europe is much warmer in winter than the eastern part; this comes about solely through the fact that in winter the transportation of air from the south takes place more actively in western Europe than it does in eastern Europe.

Hence, the main question of the causes of our phenomena of cold and heat resolves into those of the so-called circulations. In the tropical region there prevails a heat source; the air is warmed by the ground, which is heated by solar radiation. In the polar regions there prevails a cold source; the air is made cool by the ground, which is cooled by outward radiation. The result of the warming of the air in the Tropics and its cooling in high latitudes is a circulation. Aloft there is a flow of warm air toward higher latitudes and at the ground a flow of cold air toward lower latitudes.

Of course a symmetrical circulation over the whole Northern Hemisphere is precluded. The two currents can not occur in similar manner over the whole hemisphere for the reason that the rotation of the earth produces a deflecting force which causes the poleward current to undergo deviation toward the east and the equatorward current deviation toward the west. Therefore, the circulation from cold region to warm region and in the reverse direction can take place along a meridian circle only when in connection with the poleward current there lies low pressure to the west and the deflecting force of the earth's rotation is counterbalanced by the pressure gradient; in that case a current can penetrate to the Pole. On the other hand, with a current from the north, there must be present a pressure gradient toward the east in order that the cold masses may penetrate the tropical region. Thus there form between the two currents regions of high and of low pressure; for example, if a warm current flows from south to north and on its western side there flows a cold current from north to south, then between these two branches of a circulation there lies a region of low pressure, and, on the other hand, if the cold current flows on the eastern side of the warm one there lies between the two currents a region of high pressure.

Thus the cyclone and the anticyclone appear as a result of the circulation that unquestionably must result from the presence of sources of heat and cold in fluids. All air movement on the earth is made possible by heat energy. The specially intense phenomena of air movement, such as the cyclones, originate through friction between the two currents of the circulation. We may designate such cyclones friction whirls, whose axes lie not vertical but nearly horizontal. Each cyclone and each anticyclone effects, through mixing of the air, a kind of temperature adjustment with the two currents between which it lies. The main currents of the cold and of the warm air lie, however, at the sides of the true areas of the cyclones and the anticyclones and an adjustment of temperature is maintained by these two phenomena, but still not fully effected. As a result the warm air to the east of the cyclone flows still farther toward the cold region while the

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cold air west of the cyclone moves still farther toward the warm region, the south. At length the warm air masses arriving in the polar region spread toward the right and toward the left, the current divides into two or more parts and intermingles with the cold mass of air. In the south the cold current divides toward east and west; through this division the advancing cool air is warmed more and more until at length as warm air it flows from the tropical toward the polar region. By "circulation" we are to understand continuous circulatory movement of each air mass.

The stretches over which a circulation first takes place do not generally remain continuously the same. In the winter of our latitudes the oceans are relatively warmer than the continents; therefore, a warm current holds itself rather to the ocean than to the continent. Normally, however, parts of the warm current invade the continents again and again, for the most part toward the east. In analogous manner the cold currents keep rather to the cold continents, but they, too, divide and flow out over the oceans. Hence, under normal conditions the cyclones of our hemisphere migrate toward the east or the northeast, so that in reality all regions from the subtropics to the Pole are crossed by cyclones. Usually we see on the Northern Hemisphere two or three great circulations lying adjacent to one another, and, as was mentioned above, there appear small branches on both sides of the main currents. On account of the great mobility of the air, these circulations are very variable, and at present we have no rather exact knowledge of the individual phenomena. Only after observation of the momentary forms of circulation are we able to estimate the change in the same in the immediate future.

In the winter of 1928–29 the usual circulation consisting of three to four systems at the beginning gradually transformed into only two main systems of circulation; that is, into cold currents from the north over Eurasia and North America and warm currents over the Atlantic and Pacific Oceans; this was accomplished in February. The great continental region of northern Asia and northern Europe had evidently become colder and colder on account of preceding snowfall, since the outward radiation from snow cover is very intense while insolation is strongly reflected from it and effects no particular retardation of the cooling. Through this outward radiation the air at the ground had cooled more and more. On account of its greater specific gravity, it could not be removed by winds of higher temperature; the cold air masses increased in size and, as a region of high atmospheric pressure, began to spread out on all sides. This outspreading naturally took place toward warmer regions. Thus there originated cold currents toward south, east, and west, and to greater extent over the lowlands, since on account of friction at the ground the cold air mass does not advance so rapidly as the warm air mass which extends higher. The cold currents of the circulations have, therefore, for the most part a wider extension at the earth's surface than those of the warm currents.

In its western extent the cold current from the northern part of Eurasia moved in true normal manner toward southern and western Europe. This took place in connection with two warm currents that regularly occur with cold continental air—when a warm current over the Atlantic, especially one from low latitudes, advances northward at the eastern limit of the ocean the warm air can keep to the regions of the seas, the regions north and northeast of Scandinavia, and that of the Mediterranean Sea. As a result of pressure differences aloft this form of circulation carries the warm air toward the coldest surface regions, thus from the eastern part of the Atlantic Ocean over Spitzbergen and Nova Zembla toward interior Asia and also over the Mediterranean Sea toward southern Russia. With this invasion of warm air into the cold region there form on the left of the warm currents whirl formations (cyclones), through which there results lower pressure in the region of rotation between currents, and this draws in new cold masses from the left side of the current. The invasion of a warm current to the Arctic border of Russia regularly had as a result a new invasion of cold from the north toward the southwest, whereby the warm current which had entered the northern continental region was cut off by the cold current. Likewise the bending of a warm current to the east into the Mediterranean Sea regularly brought about a rotation over the Mediterranean Sea and a new invasion of cold toward Austria, and this frequently reached as far as Italy.

At the same time there is present on the western border of the cold mass, bordering the warm Atlantic current, a regular bending of the cold current from the northeast to west, northwest, and even north; without this parallel flowing of the cold border mass and the adjacent warm winds no continuing condition will be able to exist on account of the deflecting force of the earth's rotation. In this way the current from east to west and northwest came to be continuous and brought intense cooling even to England. The warm current on the west could not dissipate the cold, since there came a continuous supply of cold air masses from the east.

Southern Russia and central Europe had throughout the entire time lower temperatures than the Lofoden Islands, Iceland, and Spitzbergen. Since the warm current over the Atlantic could not shift toward the east on account of the intense cold over Eurasia, but remained over the ocean, the related cold countercurrent on the west held continuously to the region of North America. In eastern Asia the cold current continued through the cold period in that region, so the warm current to the east was limited to the Pacific Ocean. In this way there were maintained, especially after the latter half of January, only the two above-mentioned circulations over the Northern Hemisphere.

The greater the number of circulations that are present on the hemisphere the more variable becomes the weather; the fewer the circulations the more uniform the weather.

The manner in which such phenomena began with the coming winter is not known. The air mass over the earth is continually in motion, and must have in its enormously great dimensions very complicated changes in movement that are much more difficult to understand than, for example, movements of water in rivers and seas; the atmosphere has no banks or shores; the continents and the oceans alone give us a bit of understanding. Consequently, the phenomena of currents on the whole of our globe present a difficult problem which we can grasp somewhat better only gradually through investigation of the currents. The ideas that any extraterrestrial, cosmic phenomena have an influence on such weather situations appear to me to be entirely unwarranted.—*Translated by W. W. Reed.*